Beam Stabilization Efforts at the Advanced Photon Source

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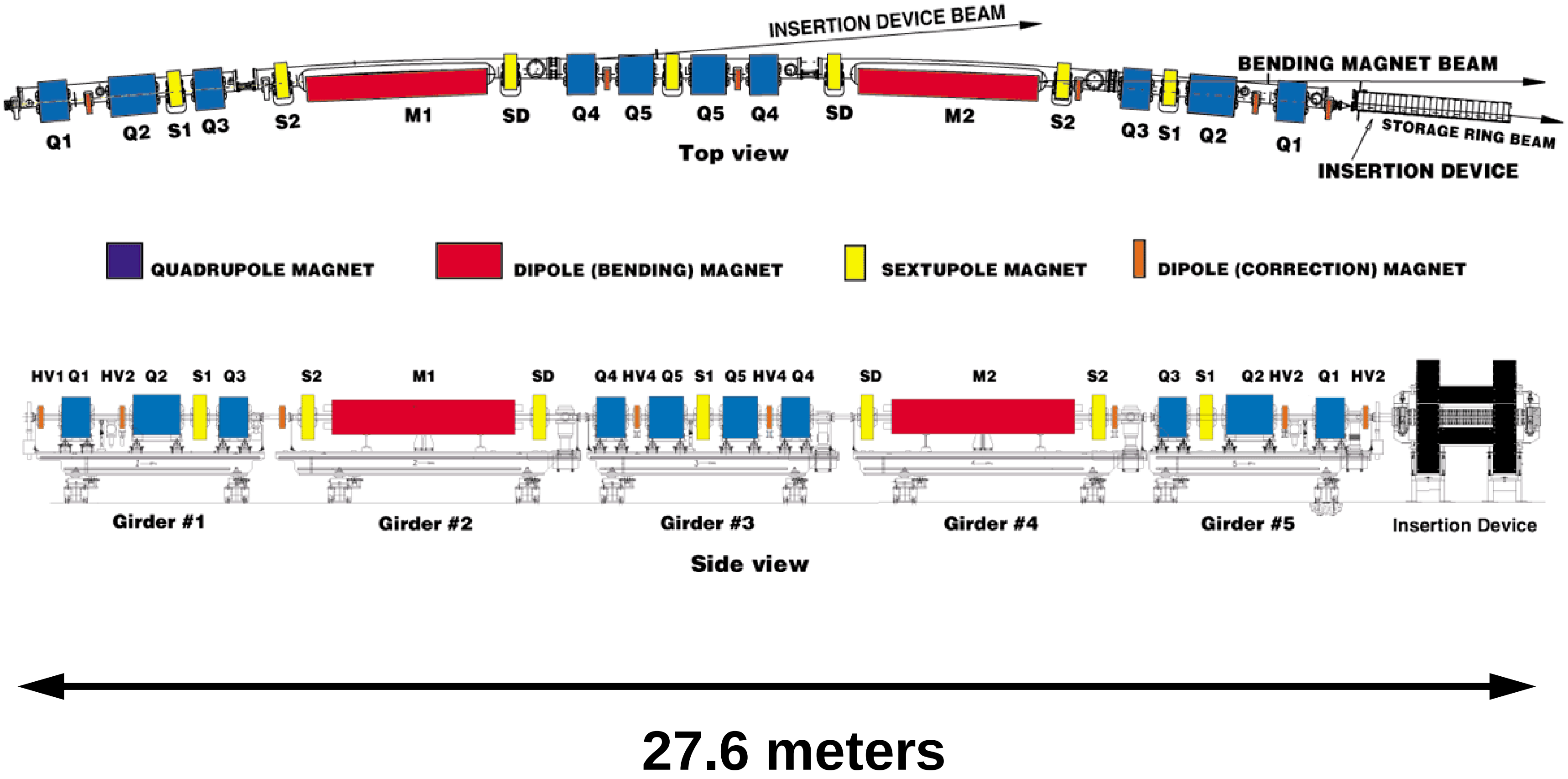
- **APS beam stability specification**
- **System overview**
- **Accomplishments to date**
- **Improvement plans**

One Sector of the Advanced Photon Source Storage Ring



(APS has forty sectors - 1104 meters total circumference)

APS Beam Stability Specification

1) Original engineering specification 5% of CDR beam size values

- 4.5 microns rms vertical (@ ID source points)
- 17 microns horizontal

2) With present low-emittance lattice, (1% coupling) this amounts to

- 590 nm / 120 nanoradians rms vertical <------
- 12.6 microns / 900 nanoradians rms horizontal

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Time scales:

- MTBF sets a limit, since x-ray optics thermal cycle dominates stability following a fault. Presently ~33 hours
- High frequency limit for spec. is 30 Hz. Most experiments effectively integrate for >> 30 milliseconds.
- For > 30 Hz, spec relaxed to ~ 50% of beam size; high frequency motion effectively increases the beam size.

APS Orbit Correction System Parameters

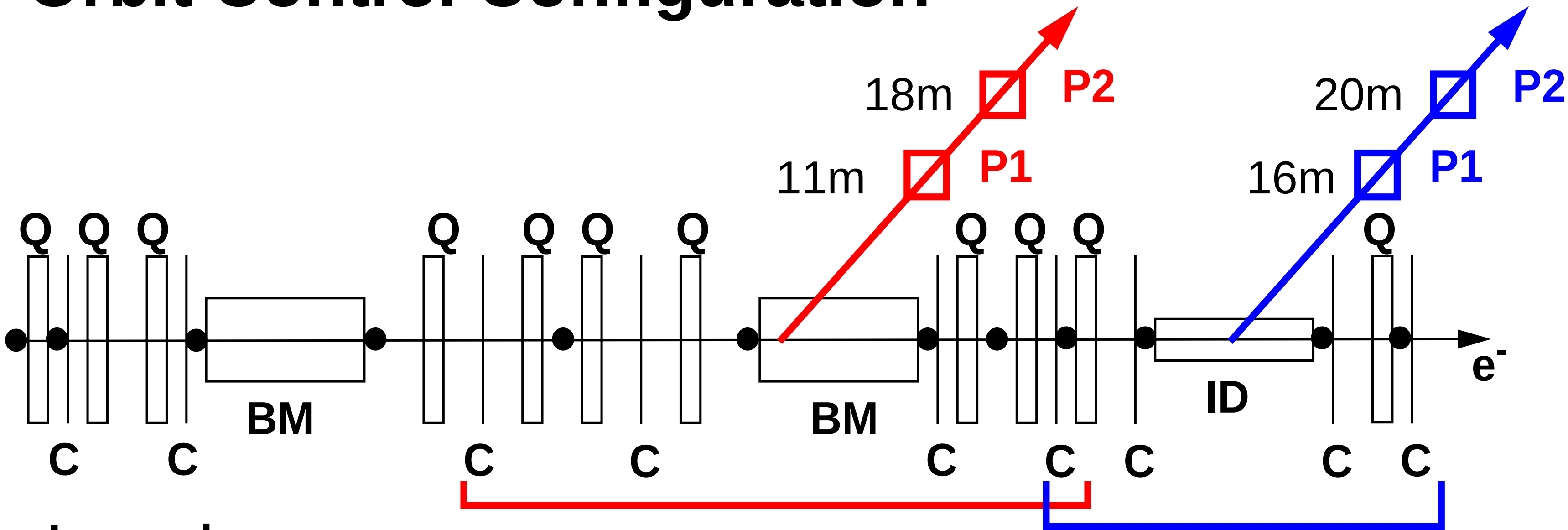
Real-time Feedback System Parameters

Number of Correctors	38
Number of BPM's	160
Number of DSP's	42+
Number of IOC's	21
Update Rate	1.5 kHz

DC Orbit Correction Parameters

Number of Correctors	318
Number of RF BPM's	410
Number of BM XBPM's	38
Number of ID XBPM's	50
Number of IOC's	1
Update Rate	1.5 Hz

Orbit Control Configuration



Legend:

C: Steering Corrector Magnet

●: RF Beam Position Monitor

P1,P2 : X-ray Beam Position Monitors

Q: Quadrupole

BM: Bending Magnet

ID: Insertion Device

Bending Magnet and BPM Layout

Insertion Device and BPM Layout

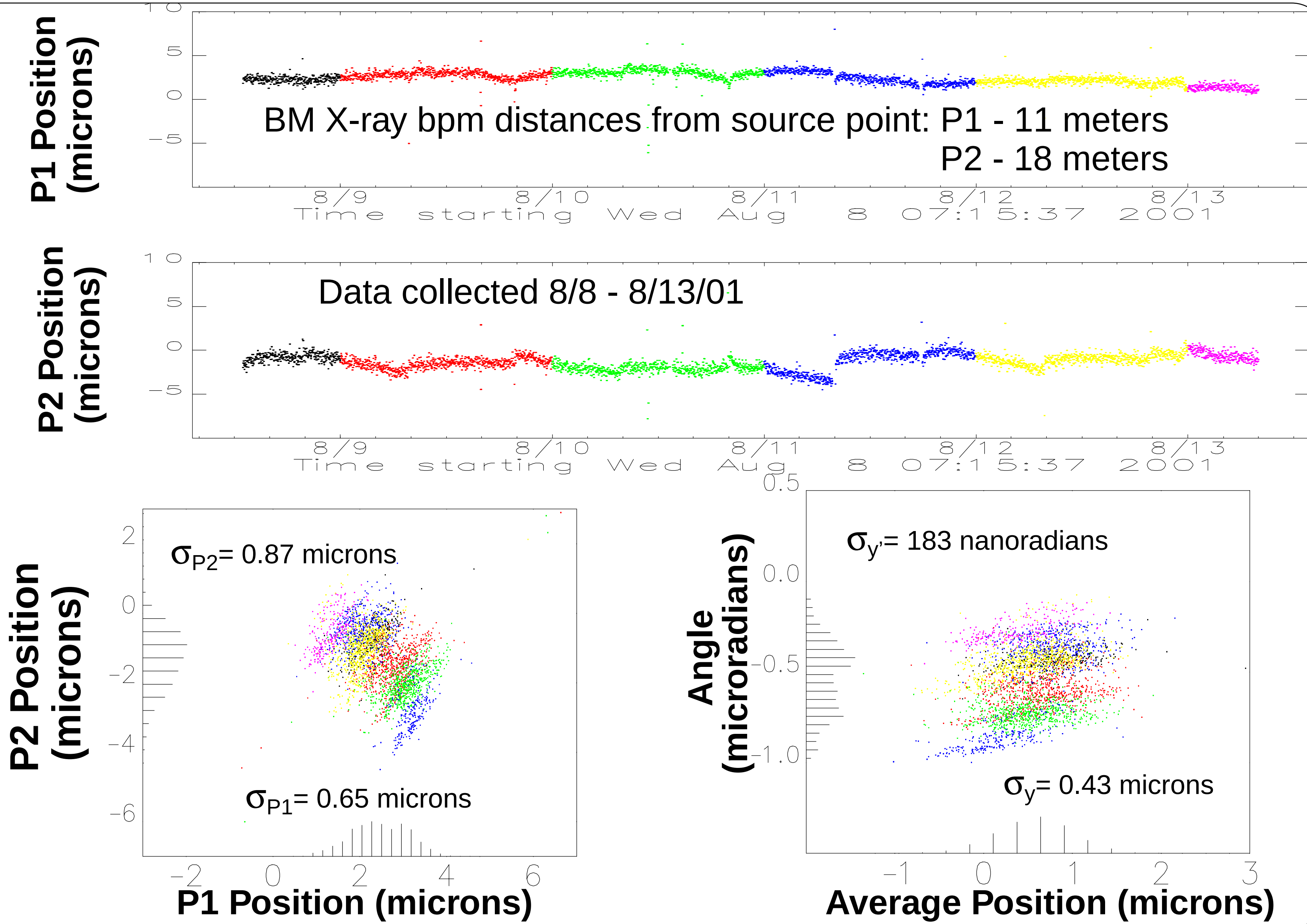
Impediments to Orbit Correction

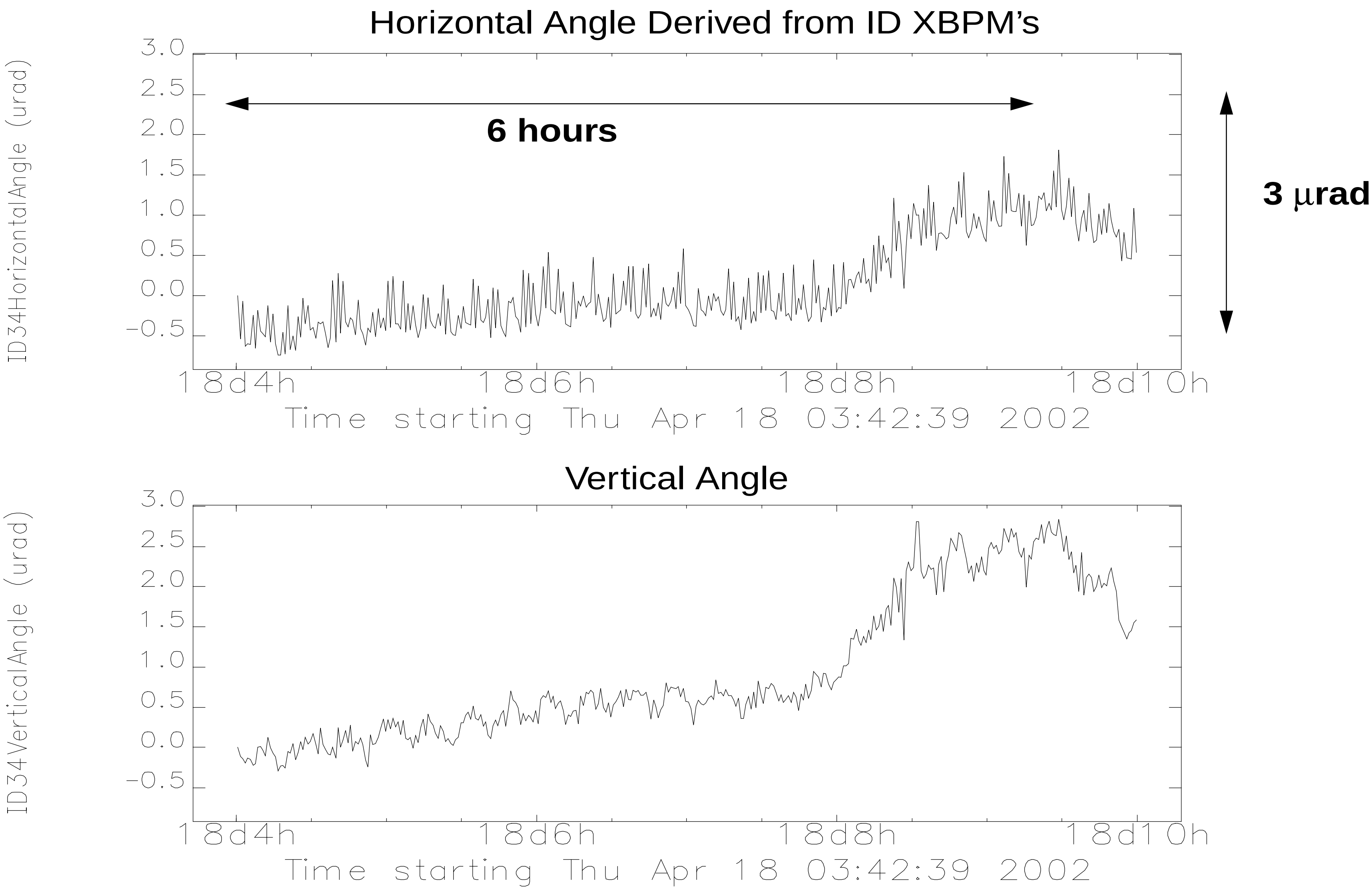
- Systematic errors, e.g.
  - Fill pattern dependence
  - Intensity dependence
  - Intermittent failure of any individual BPM or corrector
  - Stray radiation impinging upon insertion device X-BPMs
  - Electronics noise, drift
- Configuration control
  - Keeping track of “bad” bpms and correctors (and workarounds)
  - Keeping track of “in use” bpms and correctors
  - Keeping track of bpm setpoints and offsets

Noise Sources Impacting APS Orbit Stability

- **Magnet power supply noise / ripple**
  - Dominant source of beam motion
- **RF system high voltage power supply**
  - Induces 360 Hz phase ripple + harmonics impacting horz. position
- **Thermal effects (Tunnel air / water temperature)**
- **Earth tides**
- **Mechanical vibration**
  - Affects primarily horizontal beam motion
- **Insertion device gap changes**

Plots showing < 200 nanoradian rms vertical beam stability over a 5 day period
Colors indicate data for individual days

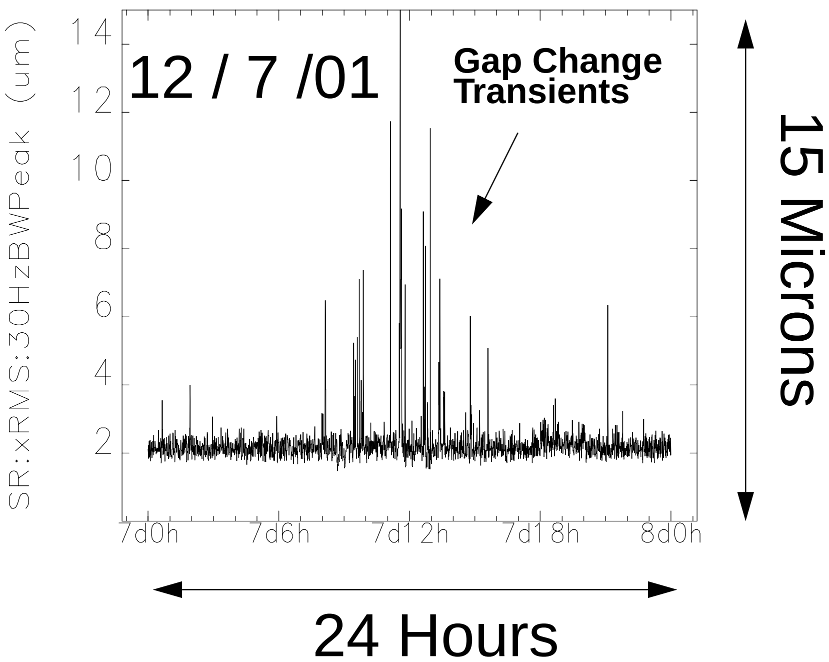




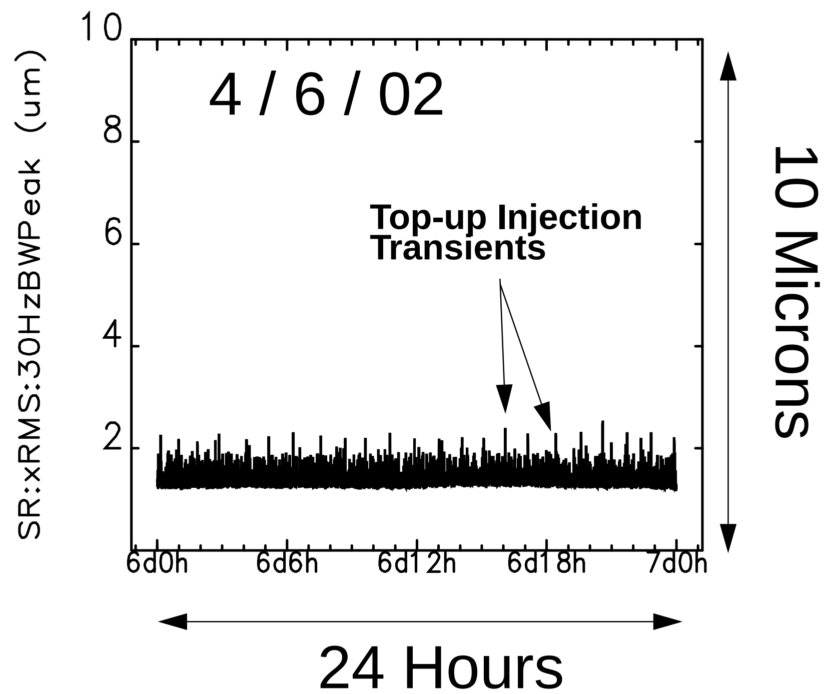
(34ID Gap = 26.78 mm)

Effect of Increased Orbit Correction Update Rate on 24-hour Horz. RMS Beam Stability 0.1-30 Hz

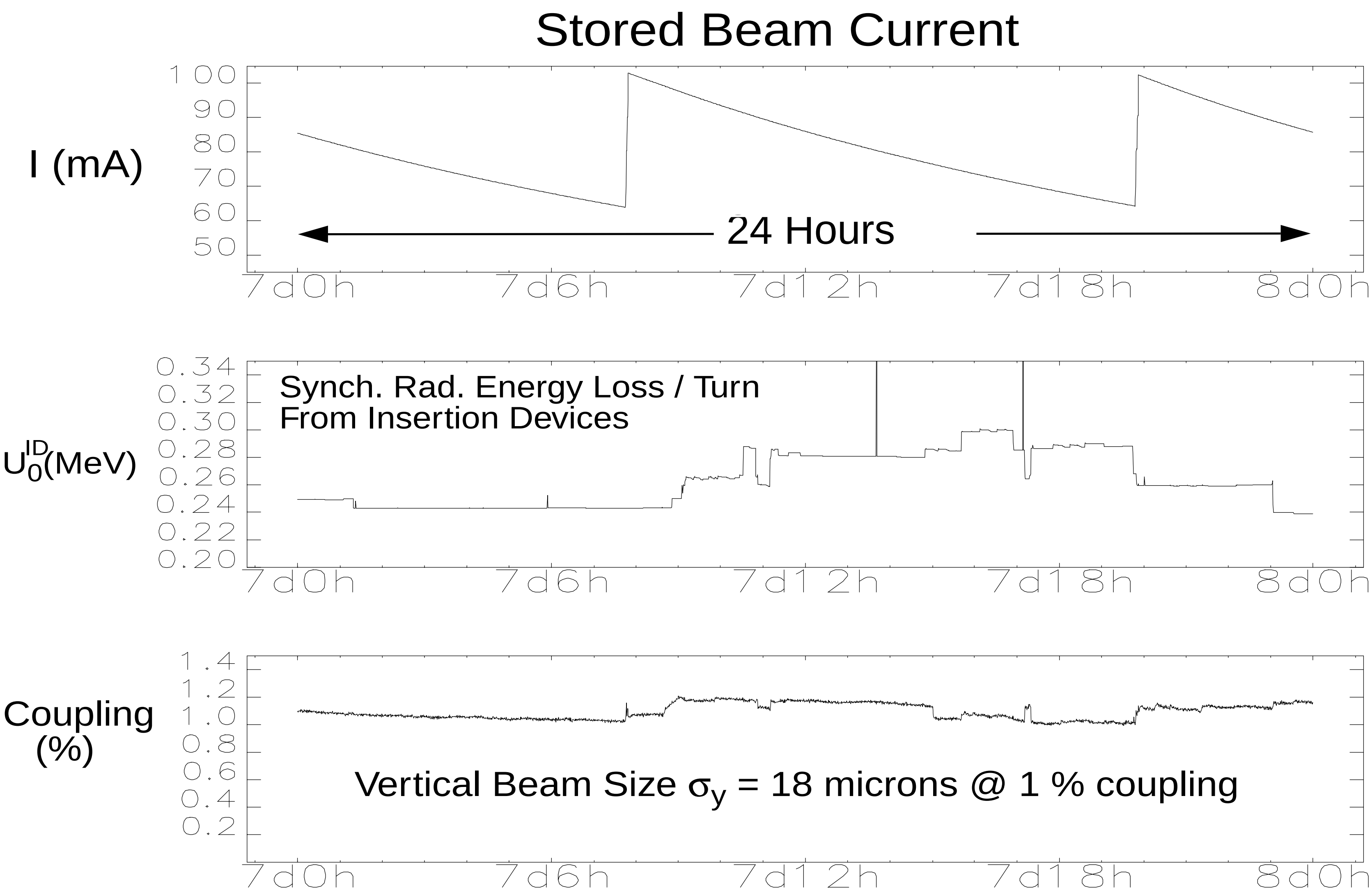
2.5 Second Update Rate



0.7 Second Update Rate



Stability of Vertical Beam Size



Upgrade Plans

- Software
  - **- Increase DC orbit correction update rate to > 20 Hz**
  - **- Integrate ID x-bpm's into DC orbit correction <-- very close**
  - **- Integrate x-bpm data into real-time feedback (1.5 kHz) system <-- long term goal**
  - **- Regulate rf frequency with to eliminate 360 Hz phase modulation sidebands**
  - **- Implement cogging**
- Diagnostics
  - **- Complete complement of narrowband bpm's <-- order being placed**
  - **- Perform cost-benefit analysis of upgrade paths for broadband rf bpm system**
- Mechanical
  - **- Regulate coupling <-- May require additional skew quadrupoles**
  - **- Upgrade x-ray bpm translation stages (required for calibration)**
  - **- Vibration source identification and remediation**
  - **- Optimize X-bpm geometry / develop new X-bpm design**
- Power supply upgrades
- Better regulation of tunnel temperature
- Accelerator / Beamline realignment
  - **- Running the beam off axis through sextupoles unnecessarily couples vibrations into the beam.**
- RF system stability improvements

Conclusions

- **There's no such thing as a beam position monitor that is only sensitive to beam position.**
- **The beam is really really tiny, and the beamlines are really really long. The ratio of the two (hundreds of nanoradians) is really really really tiny.**
- **There's no sense stabilizing the beam to a fraction of the beam size if the beam size itself isn't constant to better than the same fraction.**
- **There's no sense making the beam smaller than the amount of beam motion - it'll just get smeared out.**
- **It's only going to get harder to do in the future (i.e. more fun).**
- **Goal: Sub-micron x sub-200 nanoradian rms stability, from 5e^{-6} Hz to 30 Hz; < 5 microns rms 30 Hz - 3 MHz**